An Adaptive Field Detection Method for Bridge Scour Monitoring Using Motion-Sensing Radio Transponders (RFIDs)

Tech transfer summary

In this study, we investigated the performance and applicability of Radio Frequency IDentification (RFID) technology for detecting the onset of scour and estimating the scour depth.

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RESEARCH PROJECT TITLE
An Adaptive Field Detection Method for Bridge Scour Monitoring Using Motion-Sensing Radio Transponders (RFIDs)

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IIHR's historic C. Maxwell Stanley Hydraulics Laboratory was dedicated as a National Historic Civil Engineering Landmark in 2005, placing it among the major structures of national importance to the engineering profession. The mission of the IIHR is to conduct research in water resources and environmental engineering.

OBJECTIVES

The main objective of the study was to develop a comprehensive field detection method for the safe and reliable monitoring, inspection, and life estimation of bridge infrastructure affected by scour.

This was accomplished by integrating the RFIDs with sensing architecture for in-situ scour monitoring and multi-scale modeling to provide real-time, condition assessments that can be used in decision-making for down time, repair costs, and estimating the remaining useful life of critically scoured bridge structures.

The results from this study will ultimately translate to an inexpensive, automated bridge monitoring system with the potential applications for other critical infrastructure, such as dams, levees or other near-shore structures.

PROBLEM STATEMENT

Scour of the river bed sediment near a bridge pier or abutment results from complex interactions between the approaching streamflow and the bridge structure. If the scour is excessive, it can expose the bridge foundations and thus compromise their stability. Unfortunately, the FWHA estimates more than 150,000 bridges across the United States are vulnerable to scour. Current monitoring methods of scour require personnel to be physically present at the bridge site during the measurements, putting them at risk during a flood event. Additionally, these methods can expensive, time consuming, and often require traffic control. A remote, yet cost-effective means of monitoring scour is highly desired by DOTs around the country.

Figure 1. Measuring scour using RFIDs. (A) An IIHR student maneuvers an antenna over a scour hole. (B) A Leopold chain with RFID tags encased in a PVC tube, similar to this is buried in the river bed where the scour is occurring.

Figure 2. The location of the RFIDs in Clear Creek near the Camp Cardinal Rd. Bridge was the study's focal point.

RESEARCH DESCRIPTION

In this study, a Low Frequency (134.2 kHz), passive RFID system was developed and consisted of three main parts, namely the reader, the antenna, and the transponder (Figure 1). The system was installed and tested at bridge site in Coralville, IA (Figure 2).

The corresponding tasks of this study included the following:

1. Construct a custom-made antenna and waterproof, passive transponders optimized to obtain a maximum detection distance in different river bed sediments.
2. Install a modified Leopold chain with RFID tags in the river bed at a bridge site in Iowa to monitor scour.
3. Develop and prepare an easy-to-use software that will process the return signals and the orientation of the buried RFID tags in order to quantify scour hole development.

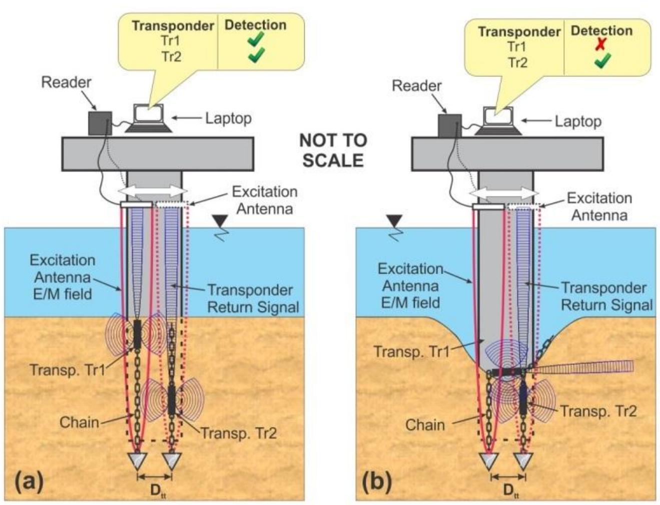

Figure 3. The signal transmitted from the RFID tags is strongest in the direction parallel to their long axis. As scour exposes the RFID tags attached to the Leopold chain, the tags will tip over. As a result, they are no longer transmitting towards the antenna and they will not be detected.

KEY FINDINGS

- A 10 ft. x 6 ft. antenna comprised of two 12-AWG-Stranded wire loops that 1.375 inches apart offered a maximum detection range of 45 ft. with a moderate inductance.
- RFID transponders, or tags, can be encased in an epoxy potting compound and placed in a watertight PVC tube so that the can be submerged in a streambed with no loss in the detection range.
- Two methods can be used with the suggested RFID system to detect scour –
    - The "folding chain" method, which utilizes the loss of tag return from a change in its orientation (Figure 3).
    - The "signal strength" method utilizes the intensity and distribution of the tag return signal. Tags exposed in water have a more peaky function than those buried in the sediment.
- An easy-to-use software developed by the research team is available that can quantify scour using both above methods.

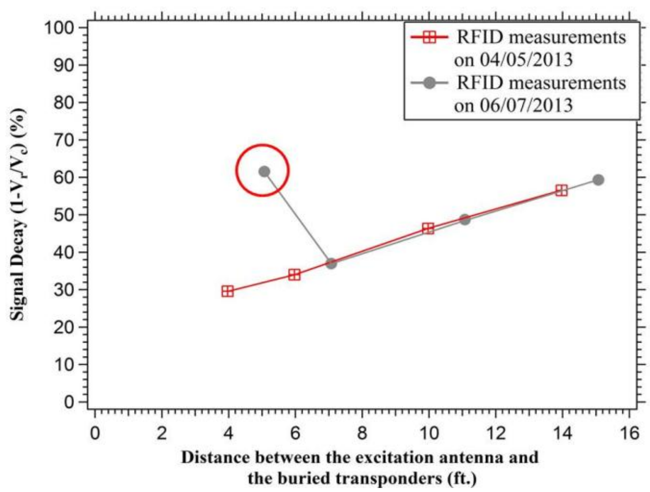

Figure 4. Processed RF signal strength decay curves corresponding to the two measurement dates during the period of 04/05/2013 and 06/07/2013.